Wrong-Way Movements on Divided Highways

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INTRODUCTION

From traffic data collected on multilane highways across the country, it has become apparent that on virtually all such facilities vehicles occasionally travel in the wrong direction. This phenomenon, known as a wrong-way movement, is a function of many factors, notably driver error, inadequacies in driver information devices, and geometric design. Wrong-way movements have a high potential to result in head-on collision-type accidents and, as such, represent a significant threat to the safety of motorists.

The important characteristic of wrong-way accidents is their severity as opposed to their frequency. General nationwide data indicates that between one-quarter and one-half of all wrong-way accidents result in one or more fatalities. In Indiana, although .67 percent of all accidents from 1970 to 1972 resulted in fatalities, 28.1 percent of all wrong-way accidents resulted in fatalities (1).* Wrong-way accidents accounted for approximately one percent of all traffic deaths in Indiana during the 1970-1972 time period (1).

Because of the seriousness of this problem, considerable research effort has been devoted to it, most notably by the state highway organizations of California, Texas, and West Virginia (2, 3, 4). In spite of these and other studies, further research in this area was warranted for the following reasons:

1. Wrong-way movements remain a continuing and significant safety problem on divided highways.

* Numbers in parentheses denote references at end of paper.

2. Both statistically and practically, wrong-way movements are a very rare event. As a result, it is difficult to establish definitive causal relationships between wrong-way movements and roadway movements and roadway elements. Improvement of the data base will ameliorate this problem.
3. Research into this problem may assist in identifying alternatives to reduce the seriousness of the problem.

The Indiana State Highway Commission, recognizing the wrong-way accident problem, participated in a study of it on Indiana highways. The study (1), sponsored by the commission and Purdue University, utilized the accidents records of divided highways in Indiana for the years 1970, 1971, and 1972 as a data base. The objectives of the study were to make:

1. A quantitative assessment of the frequency of wrong-way movements on divided highways in Indiana with and without fully-controlled access.
2. An evaluation of the influence existing geometric design practices, including channelization and median design, have on the frequency of wrong-way movements on divided highways.
3. An evaluation of the effects existing driver information practices have on the frequency of wrong-way movements on divided highways.
4. Proposals for alternative geometric design practices to reduce the frequency of wrong-way movements on divided highways.
5. Proposals for alternative driver information practices to reduce the frequency of wrong-way movements on divided highways.

It was hoped that the fulfillment of these objectives would result in a meaningful response to the general problem of understanding the causes of, and ultimately reducing, the frequency of wrong-way movements and accidents.

The initial step in this study was a review of all accidents that occurred on all divided highways in Indiana during the years of 1970, 1971, and 1972. From these accidents, all those that involved a wrong-way movement were selected; 96 such accidents were found. Various characteristics of these accidents were identified and examined, including:

1. Numbers and locations of the accidents.
2. Types and severity of the accidents.
3. Times and dates of the accidents.

4. Environment conditions when and where the accidents occurred.
5. Ages of the drivers involved in the accidents.
6. Sobriety of the drivers involved in the accidents.
7. Fatigue, if present, of the drivers involved in the accidents.

Following the collection of these data from the accident records, a field inspection of each area where a wrong-way accident occurred was made. Particular emphasis was placed on locating and studying the location where the wrong-way movement, leading to the wrong-way accident, originated. At these origin locations, data were collected on the physical characteristics of both the area and the roadway and also on traffic control and/or driver information systems located in the vicinity.

Based on the data collected, causes of wrong-way movements were identified and preventive measures responsive to these causes were developed. Within this paper, some of the highlights and major findings of the study are presented.

WRONG-WAY ACCIDENT CHARACTERISTICS

The 96 wrong-way accidents occurring in Indiana during the study period were on virtually all types of divided highways within the state.

The breakdown of wrong-way accidents by road types is as follows:

1) State or U.S. routes had 58 accidents.
2) Interstate routes had 38 accidents.

Using access classification as the criteria, the breakdown is:

1) Fully-controlled roads had 40 accidents.
2) Not fully-controlled roads had 56 accidents.

Examining the access classification variable more closely, it was found that wrong-way accidents were more frequent on highways without fully controlled access, both in terms of accidents/mile and accidents/vehicle-mile.

Type and Severity

Because of their nature, wrong-way accidents are generally of the head-on type, although the data showed that this was not always the case. Often wrong-way vehicles caused right-way vehicles to run off the road or to sideswipe when trying to avoid a collision. Table 1 lists these data.

TABLE 1 WRONG-WAY ACCIDENTS BY TYPE

Type	Number
Head-on	69
Sideswipe	2
Rear-end	4
Run-off-the-road	6
Right-angle	8
Head-on with secondary collisions	6
TOTAL	95*

* All of the 96 accidents did not have all data available.

Of the 96 wrong-way accidents studied:
27 had one or more fatalities
29 had one or more injuries but no fatalities
40 had property damage only

Wrong-way casualties for the three-year study period were 39 dead and 74 injured.

TABLE 2 ACCESS CONTROL VERSUS WRONG-WAY ACCIDENT SEVERITY

Access Type	Fatal Accidents	Injury Accidents	Property Damage Accidents
Fully Controlled	17	12	8
Not Fully Controlled	10	17	32

In Table 2, the wrong-way accidents are broken down by access type and severity. Clearly, wrong-way accidents occurring on highways with fully controlled access are more severe than on highways without control, probably because of the higher speeds on such facilities. Fully controlled highways had 46 percent fatalities, while highways without full-access control had only 17 percent.

Using accident costs data developed by Winfrey (5) and projected to 1972 using a five percent per year compounded interest, yearly costs of wrong-way accidents to the state were calculated. Costs were assigned to each accident type and multiplied by the number of accidents. The yearly cost of wrong-way accidents for Indiana was over $121,000.

Time and Date

Figures 1, 2, and 3 present time and date of occurrency data on Indiana's wrong-way accidents. Where the data does not sum to 96 accidents, information was not available.

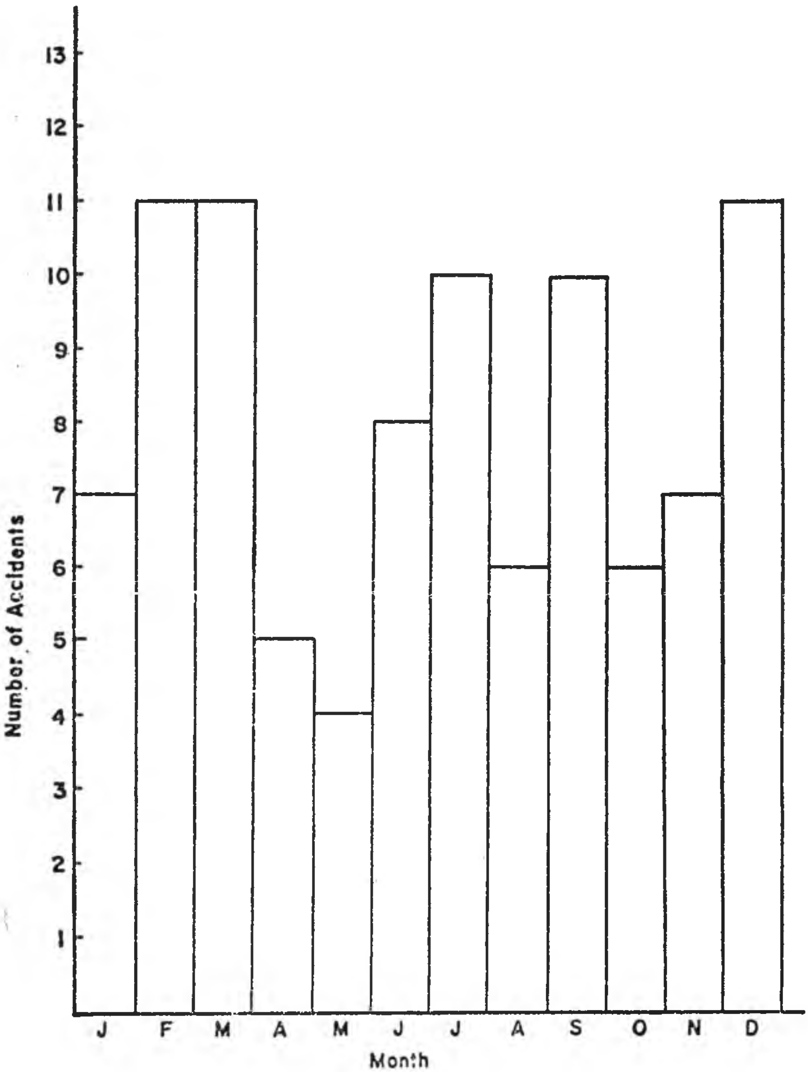

Fig. 1. Wrong-Way Accidents by Month of Occurrence.

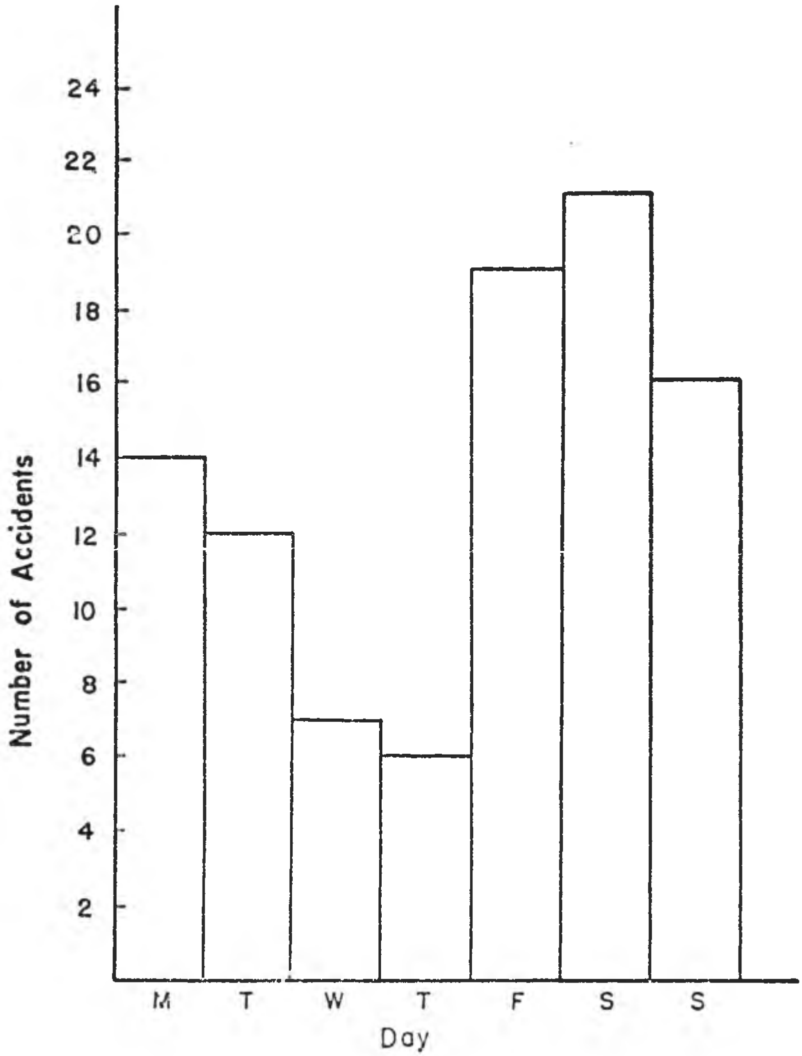

Fig. 2. Wrong-Way Accidents by Day of Occurrence.

Interpreting these graphs, it can be noted that there is little significance in the monthly distribution of wrong-way accidents. However (Figure 2) wrong-way accidents are concentrated on Friday, Saturday, and Sunday. In the literature this has been attributed to the greater number of drunken drivers on the road on these days. In Figure 3, wrong-way accidents occur more frequently than average between the hours of 6 p.m. and 4 a.m. This phenomenon has been

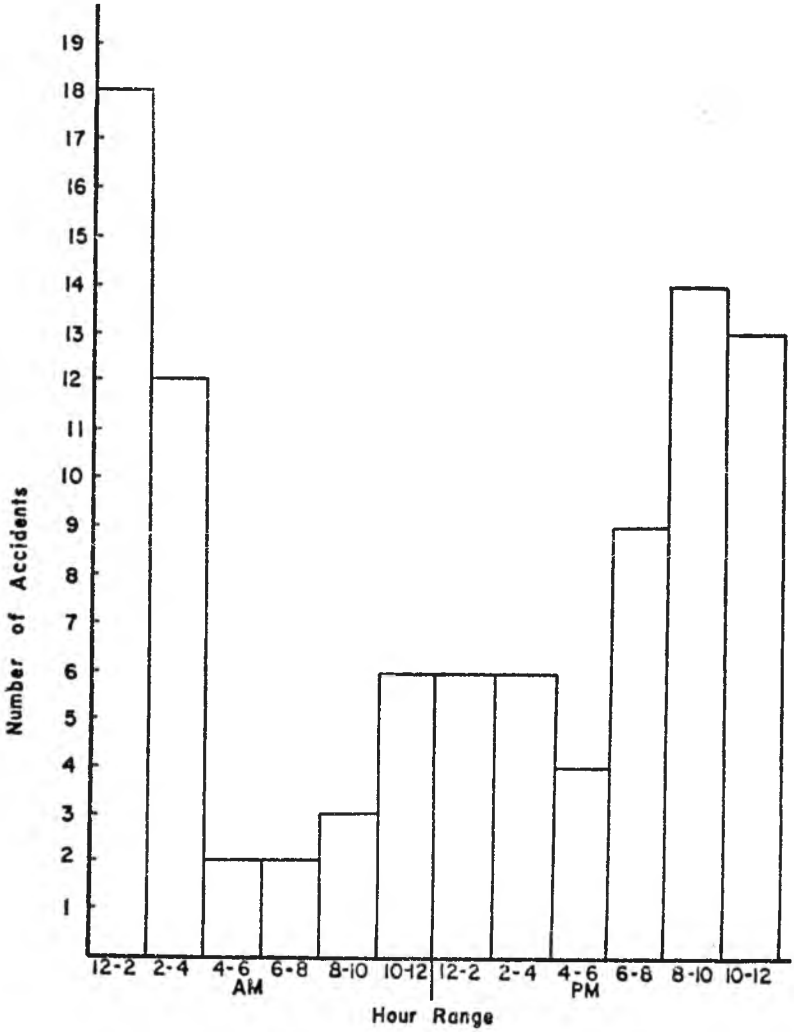

Fig. 3. Wrong-Way Accidents by Hour of Occurrence.

variously explained by reduced visibility during these hours and the greater tendency for drivers to be fatigued and/or drunk during these hours.

Environmental Factors

Data on environmental factors pertaining to where and when the wrong-way accidents occurred were available from the accident reports. Three factors—weather, visibility and land-use—were considered in this phase of the analysis; due to the nonnumerical nature of these parameters, qualitative terms were employed as parameter levels.

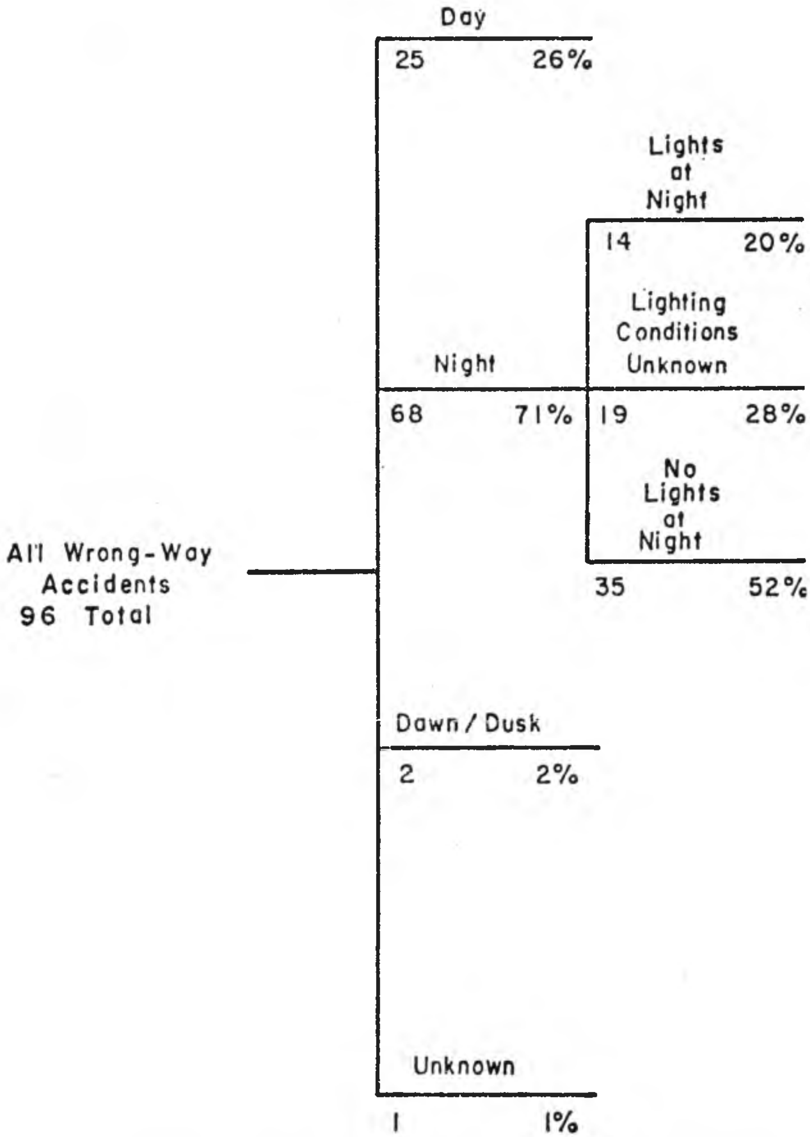

Fig. 4. Visibility Conditions at Wrong-Way Movement Origin Areas.

The weather at the time and location of the accidents was as follows:

74 accidents occurred during clear weather
5 accidents occurred during rain
4 accidents occurred during snow
1 accident occurred during fog

The weather conditions were not known for 12 accidents. In the majority of the accidents, the weather was dry and clear leading to the finding that weather was not a significant variable in wrong-way accident causation.

Visibility conditions at wrong-way accident sites were generally poor as most of the accidents occurred at night on unlit portions of a highway. Figure 4 shows the visibility situation at the area where the wrong-way movement, leading to the wrong-way accident, began. Interpreting Figure 4, 35 accidents occurred under conditions of darkness, 16 during conditions of marginal visibility (dawn, dusk, or lighted area at night), 25 during daylight, and 20 under unknown lighting conditions. Most of the 20 accidents in the last category probably occurred either under marginal conditions or in darkness.

Data on the area land-use of the wrong-way movement origins are presented in Table 3. The wrong-way movement origin tended to occur in areas of low land-use density.

TABLE 3 WRONG-WAY MOVEMENT ORIGIN AREA'S LAND-USE TYPE AND DENSITY

		LAND-USE TYPE			
		Commercial	Farm	Industrial	Residential
LAND-USE DENSITY	Very Light	4	25	0	3
	Light	5	10	3	14
	Medium	7	0	0	1
	Heavy	4	0	0	0

WRONG-WAY DRIVER CHARACTERISTICS

An examination of driver characteristics is important, because wrong-way movements are primarily caused by breakdowns in the highway and/or driver communication system. Within this chapter factors that possibly contribute to this breakdown are raised and discussed. These factors are:

1) Age
2) Sobriety
3) Fatigue

Age

Eighty-one observations on wrong-way drivers' age were available from accident record data. Table 4 was generated by breaking down wrong-way accidents by age group. Both older and younger drivers are disproportionately represented in terms of the data developed suggesting that age is related to wrong-way movement proneness. The available information on this problem was not sufficient to definitely ascertain the nature of the relationships; however, other research (7) has shown that driving abilities, in terms of wrong-way accidents, increase and then decline with increasing driver's age.

TABLE 4 WRONG-WAY ACCIDENT DISTRIBUTION BY AGE GROUP

Age Range	Number of Wrong-Way Accidents
0-20	6
21-30	21
31-40	13
41-50	13
51-60	10
61-70	10
Over 70	8

Sobriety

Driver sobriety was one factor that clearly stood out as a cause of wrong-way accidents. In 19 of 96 wrong-way accidents, the sobriety of the driver was not known; however, of the 77 in which it was known, the driver was drunk 54.6 percent of the time (42 observations of drunkenness). This is very probably a far higher percentage than would be true for a sample of 77 random drivers.

The reduction in mental capabilities caused by alcohol seems to increase the tendency of drivers to make wrong-way movements.

Fatigue

The information available did not provide a direct measure of driver fatigue, forcing the use of a somewhat circumspect methodology. If fatigue is assumed to be highly correlated with time of accident, the data shown in Figure 3 are of considerable use. Thirty-three of all wrong-way accidents occurred between the hours of midnight and 6 a.m., times when drivers are likely to be fatigued.

To complete this analysis, the three wrong-way driver variables were overlayed on each other to determine the number of drivers adversely influenced by at least one of the driver variables. The meaning of "adverse influence" is subjective. For the purposes of the analysis the following definitions were used:

Age: Over 65 years old
Sobriety: Driving under the influence of alcohol
Fatigue: Driving between midnight and 6 a.m.

Using these definitions, Figure 5 was developed. The problem of the wrong-way driver is illustrated graphically—only 31 percent were not adversely influenced by one or more of the three variables. In general, it appears that drivers who are older, drunk, or driving late at night are far more likely to be involved in wrong-way accidents than other drivers.

WRONG-WAY MOVEMENT ORIGIN LOCATIONS

Two problems were encountered in working with the material pertaining to wrong-way movement origin locations. First, the origin of a wrong-way movement was often not indicated in the accident report and could only be estimated from a field inspection. Second, there was no quantitative measure of most of the parameters that were considered important. The net effect of these two problems was to force the use of a qualitative analysis of the origin locations of the 57

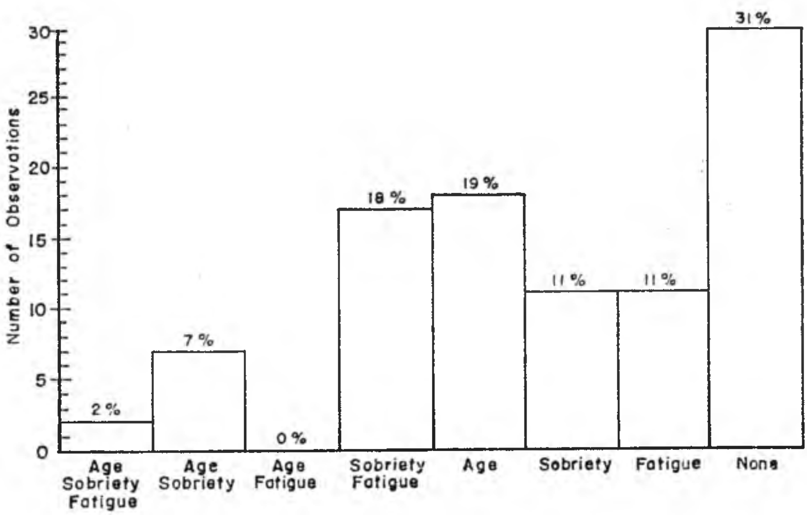

Fig. 5. Adverse Influence Factors on Wrong-Way Accidents.

(of 96 total) wrong-way accidents where origin location could be determined.

Data Presentation

On the basis of an initial review of the data, the wrong-way movement origin sites were divided into six general categories. These categories were:

1. Diamond and parclo interchanges.
2. Cloverleaf and directional interchanges.

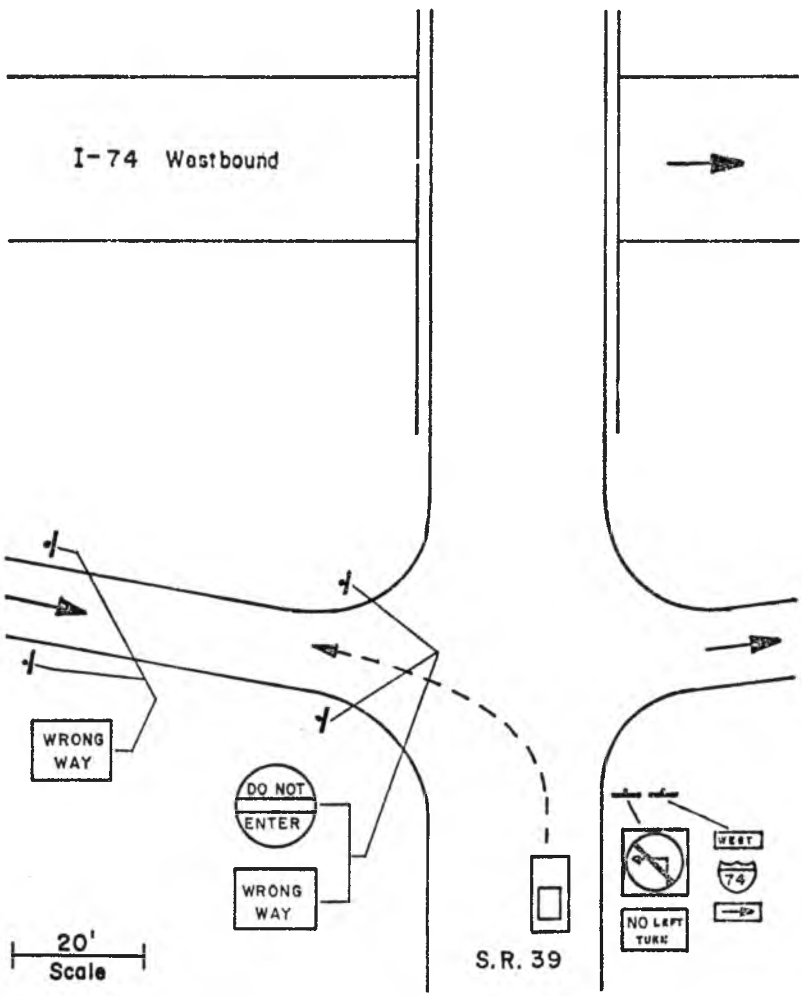

Fig. 6. The Interchange of I-74 and State Road 39—A Typical Diamond Interchange Where a Wrong-Way Movement Occurred.

3. Major intersections.
4. Minor intersections.
5. Driveways.
6. Transitions.

The second category, cloverleaf and directional interchanges, could not be analyzed because of inadequate data. Examples and discussion of the other five categories were analyzed and the results are presented in the following sections.

Diamonds and Parclos—Figure 6 illustrates a typical wrong-way access point of this category. It is in a diamond interchange providing access to Interstate 74 from State Road 39. The crossroad is two-lane, undivided, and the exit ramp has wrong-way signing. Area land-use is light. The driver who made the wrong-way movement here was very old and apparently became confused as he asked a gas station attendant for directions three times. While it was not possible to assign a certain cause to this wrong-way movement, the driver's reduced ability was probably a major factor.

Information on the characteristics of the diamond and parclo interchanges where wrong-way movements had originated (a total of 24 accidents) is presented in Table 5. Wrong-way movements tended to occur at interchanges where lighting was inadequate, traffic volumes were low, and land-use was light. Signing was generally good and the overall interchange layout was not confusing. Channelization and curbs to restrict vehicle paths were installed at some locations, but were missing in most locations.

Major Intersections—In Figure 7, the intersection of U.S. 40 and State Road 267, one of the major intersection category where a wrong-way movement began, is shown. Although the intersection's signing is good, the width of the median does not permit the approaching driver to visualize the total intersection where vehicles on U.S. 40 must traverse a wide, unchannelized space to make a left turn correctly. The accident which originated here occurred at night and the lighting was poor. Some commercial development exists on U.S. 40 east of the intersection. The driver of the wrong-way vehicle was drunk.

This wrong-way movement was probably caused by a combination of poor lighting, the driver's condition, and the geometric layout of the intersection.

The data collected at major intersections where wrong-way movements (seven accidents) originated are presented in Table 6. A major intersection was defined as one with any type of signalization. The

TABLE 5 DATA ON DIAMOND AND PARCLO WRONG-WAY MOVEMENT ORIGIN SITES*

		Confirmed	Probable†
Interchange configuration simple and non-confusing	yes	5	15
	no	0	4
Channelization and curbs to restrict vehicle paths	installed	3	5
	not installed	2	14
Signing quality	satisfactory	5	14
	minimal	0	5
Lighting at the time of the wrong-way movement	daylight	3	1
	night but with artificial lighting	1	3
	night	1	15
Area land-use intensity	none or one building	3	16
	two or three buildings	2	3
	more than three buildings	0	0
Approximate traffic volumes on the divided highway at the time of the wrong-way movement	less than 100 v.p.h.	2	16
	100 to 300 v.p.h.	2	2
	more than 300 v.p.h.	1	1

* The number of wrong-way movements originating from an access point of this type.
† The origin points for some wrong-way movements were not known with complete certainty.

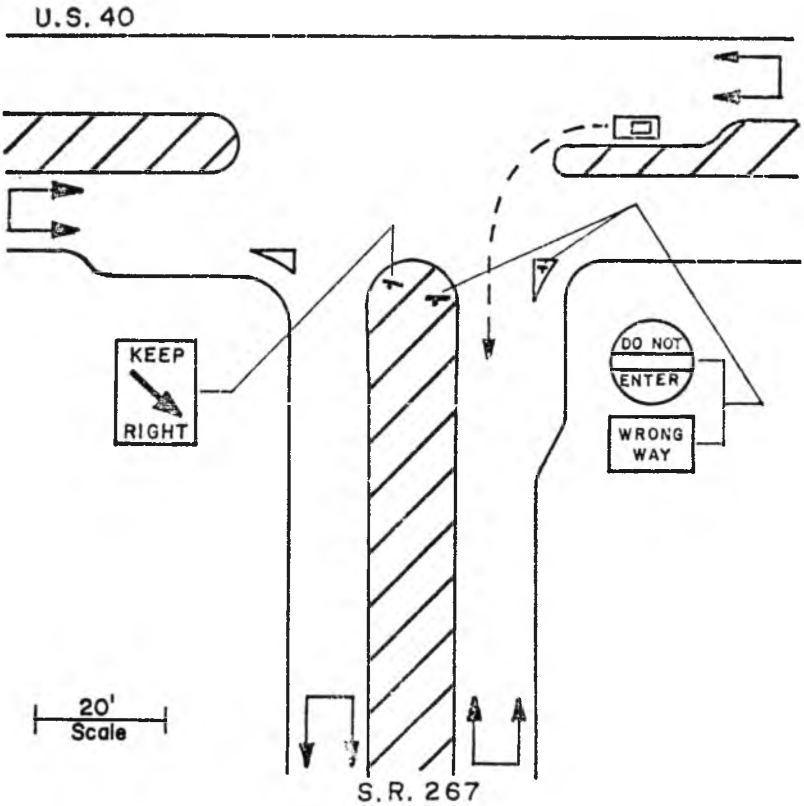

Fig. 7. The Intersection of U.S. 40 and State Road 267—A Major Intersection Where a Wrong-Way Movement Occurred.

data for all major intersection parameters was sparse and inconclusive as to factors which were important.

Minor Intersections—The intersection of U.S. 24 and Cherry Lane near Fort Wayne (Figure 8) is a minor intersection providing access from a residential area to U.S. 24. Although overall intersection visualization is very good, the intersection lacks any type of directional signing. The accident here occurred on a dark, rainy night with very low visibility. With no directional signing, the driver apparently became confused and made a left turn into the wrong lanes.

The data (11 accidents) on minor intersections are presented in Table 7. Wrong-way movements tended to occur at minor intersections located in areas of light land-use and poor lighting. All medians at these intersections were greater than ten feet in width and the presence

TABLE 6 DATA ON MAJOR INTERSECTION WRONG-WAY MOVEMENT ORIGIN SITES

		Confirmed	Probable
Crossroad elevation higher	yes	3	1
	no	3	0
Median width	less than 10 feet	2	0
	more than 10 feet	4	1
Median well delineated	yes	3	1
	no	3	0
Signing quality	satisfactory	3	1
	minimal	3	0
Lighting at the time of the wrong-way movement	daylight	2	1
	night but artificial lighting	2	0
	night	2	0
Area land-use intensity	none or one building	2	0
	two or three buildings	4	0
	more than three buildings	0	1
Approximate traffic volumes on the divided highway at the time of the wrong-way movement	less than 100 v.p.h.	2	0
	100 to 300 v.p.h.	3	0
	more than 300 v.p.h.	1	1

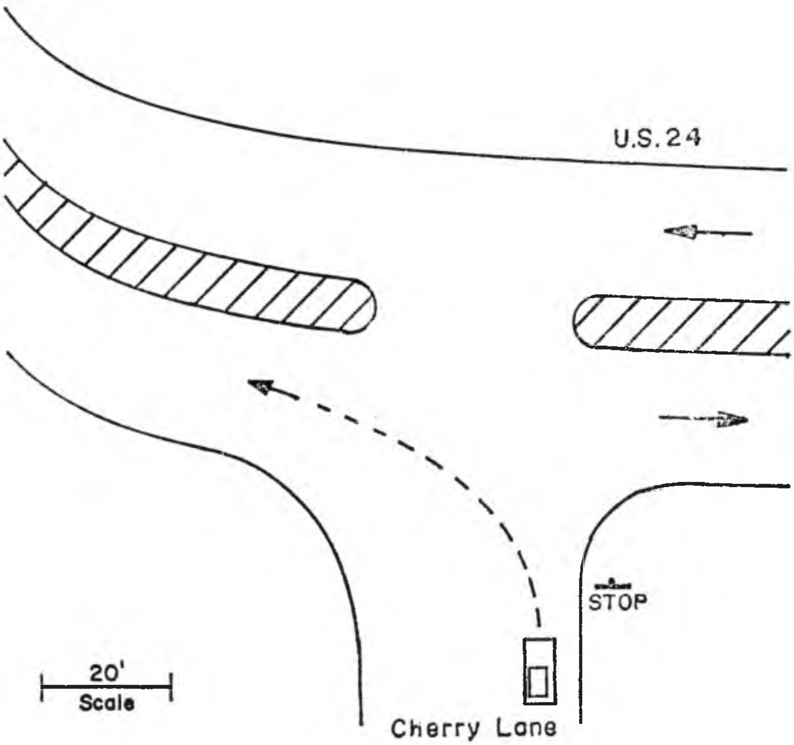

Fig. 8. The Intersection of U.S. 24 and Cherry Lane—A Typical Minor Intersection Where Wrong-Way Movement Occurred.

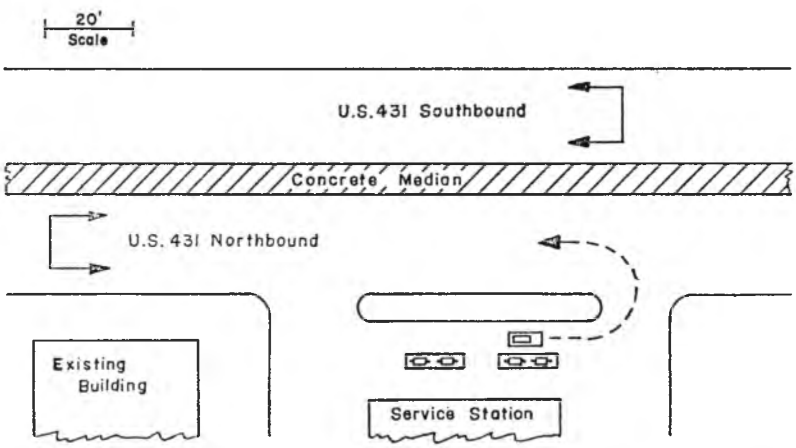

Fig. 9. Driveway on U.S. 431—Typical Driveway Where a Wrong-Way Movement Occurred.

TABLE 7 DATA ON MINOR INTERSECTION WRONG-WAY MOVEMENT ORIGIN SITES

		Confirmed	Probable
Crossroad elevation higher	yes	1	4
	no	0	6
Median Width	less than 10 feet	0	0
	more than 10 feet	1	10
Median well delineated	yes	1	7
	no	0	3
Signing quality	satisfactory	0	6
	minimal	1	4
Lighting at the time of the wrong-way movement	daylight	0	3
	night but artificial lighting	0	1
	night	1	6
Area land-use intensity	none or one building	1	9
	two or three buildings	1	0
	more than three buildings	0	1
Approximate traffic volumes on the divided highway at the time of the wrong-way movement	less than 100 v.p.h.	0	4
	100 to 300 v.p.h.	1	5
	more than 300 v.p.h.	0	1

of a divided roadway was clearly evident in most cases. The quality of signing varied as did traffic volumes.

Driveways—A typical wrong-way movement originating from a driveway is shown in Figure 9. There was no directional signing and it is likely that a directional, channelized driveway exit could have prevented the wrong-way movement which began here.

Wrong-way movements originating from driveways were somewhat infrequent (five accidents, see Table 8) and trends are not easily identified. Like other wrong-way movement origins, land-use was not usually intense. Signing was minimal or nonexistent and directional exits were not used.

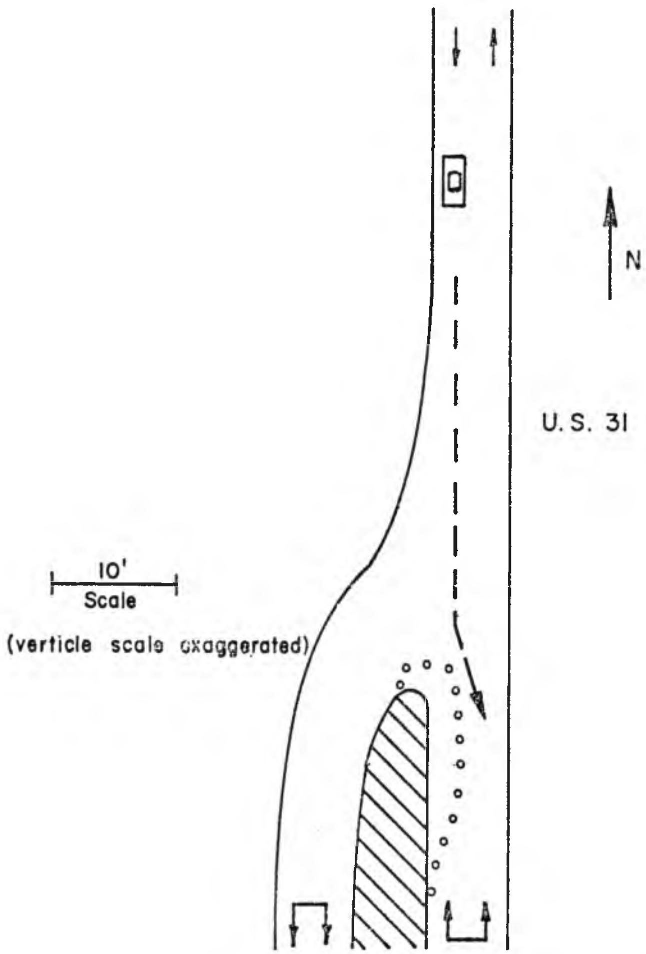

Fig. 10. Transition on U.S. 31—Site of Seven Wrong-Way Accidents.

TABLE 8 DATA ON DRIVEWAY WRONG-WAY MOVEMENT ORIGIN SITES

		Confirmed	Probable
Crossroad elevation higher	yes	1	0
	no	0	4
Median width	less than 10 feet	1	2
	more than 10 feet	0	2
Median well delineated	yes	1	1
	no	0	3
Signing quality	satisfactory	0	0
	minimal	1	4
Median opening opposite driveways	yes	0	4
	no	1	0
Directional exit	yes	0	0
	no	1	4
Lighting at the time of the wrong-way movement	daylight	1	2
	night but artificial lighting	0	0
	night	0	2
Area land-use intensity	none or one building	0	4
	two or three buildings	0	0
	more than three buildings	1	0
Approximate traffic volumes on the divided highway at the time of the wrong-way movement	less than 100 v.p.h.	0	2
	100 to 300 v.p.h.	0	2
	more than 300 v.p.h.	1	0

TABLE 9 DATA ON TRANSITION WRONG-WAY MOVEMENT ORIGIN SITES

		Confirmed	Probable
Median well delineated	yes	0	0
	no	2	1
Configuration conducive to wrong-way movements	yes	2	1
	no	7	0
Signing quality*	satisfactory	2	0
	minimal	0	1
lighting at the time of the wrong-way movement	daylight	1	0
	night but artificial lighting	0	0
	night	8	1

* Data were unavailable in seven cases.

Transitions—Seven accidents occurred at the transition on U.S. 31 north of Kokomo (Figure 10). This transition, used before all of U.S. 31 was improved to a divided, four-lane highway, had a configuration conducive to wrong-way movements. Vehicles approaching the four-lane section had to bear right to avoid driving into the wrong lanes of the divided highway. Most of the accidents also happened at night. Generally, the configuration of this transition and the inability of the driver to see the overall transition area were responsible for its wrong-way movement problem.

Trends concerning transitions (10 accidents) were difficult to establish (Table 9). However, poor lighting and the configuration of the transitions tended to cause wrong-way movements.

SUMMARY

1. Most wrong-way movements tended to originate from areas of light land-use, regardles of the type of access. This indicates that potential wrong-way origin points in such areas should receive special consideration.
2. Wrong-way movements tended to take place when traffic volumes were low. When low volumes exist, other traffic is not present near the wrong-way access point to indicate the correct direction of travel for each roadway.
3. Wrong-way movements tended to take place at times when visualization of the entire intersection was difficult or impossible. Artificial lighting would probably reduce the frequency of wrong-way movements at most access points.
4. Directional signing at most origin points appeared to be adequate. Driveways were the exception, where little or no signing was the rule.
5. Design elements that tended to reduce the driver's ability to see and understand overall access point configuration tended to increase the frequency of wrong-way movements.

GEOMETRIC DESIGN MODIFICATIONS TO REDUCE THE FREQUENCY OF WRONG-WAY MOVEMENTS

One way to reduce the frequency of wrong-way movements is through modifications in geometric design. Four general types of locations were found where such modifications would be helpful:

1. The crossroad (exit) ramp interface of diamond and parclo interchanges (highways with fully controlled access).

2. Certain types of intersections (highways without fully controlled access).
3. Driveways (highways without fully controlled access).
4. Transitions from undivided to divided highways (highways without fully controlled access).

Parclo and Diamond Interchanges

In Figure 11, a wrong-way right turn would be far more difficult or impossible if the curb on the right side of the vehicle was barrier-

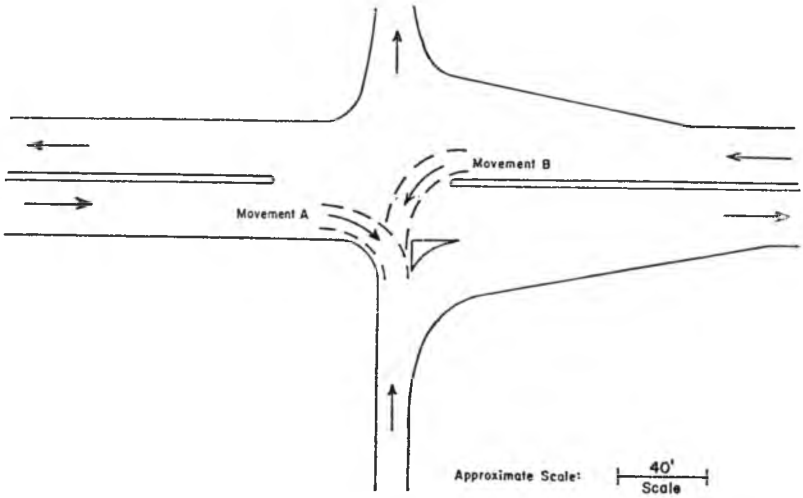

Fig. 11. Wrong-Way Movements at a Divided Diamond Interchange.

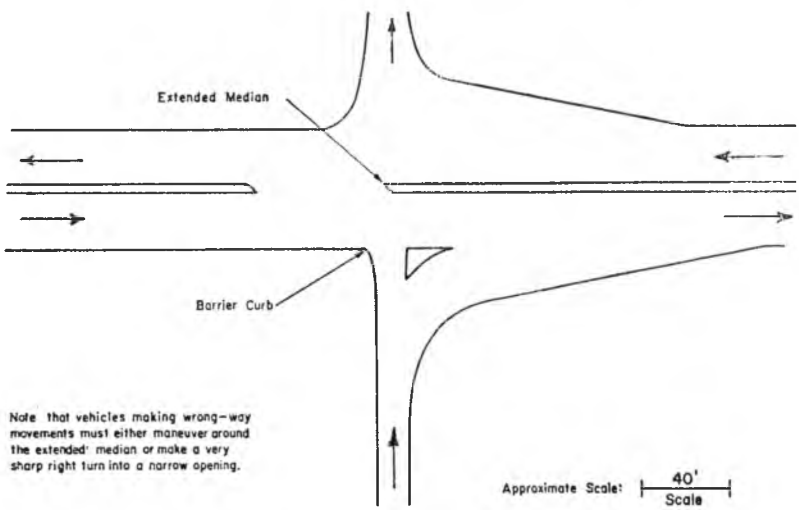

Fig. 12. Wrong-Way Movement Prevention Modifications.

type and of very small radius. Also, the turn would be more difficult if the off-ramp opening was narrowed to approximately 12 feet and th island forming the other side of the opening was curbed. These possible design changes are shown in Figure 12. Likewise, the difficulty of a wrong-way left turn could be increased by extending the median nose across the off-ramp opening, thus blocking the opening from left-turning vehicles.

Similar techniques can be used to protect parclo off-ramp openings from wrong-way movements (see Figure 13). A wrong-way right turn would be made more difficult by shortening the right-hand curb radius

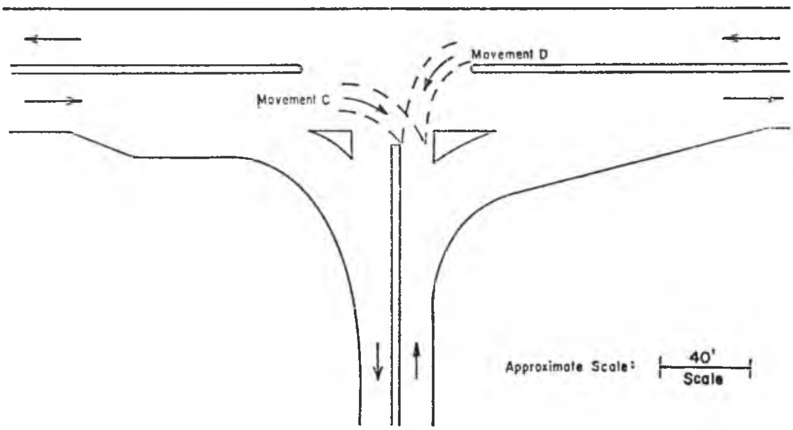

Fig. 13. Wrong-Way Movements at a Divided Parclo Interchange.

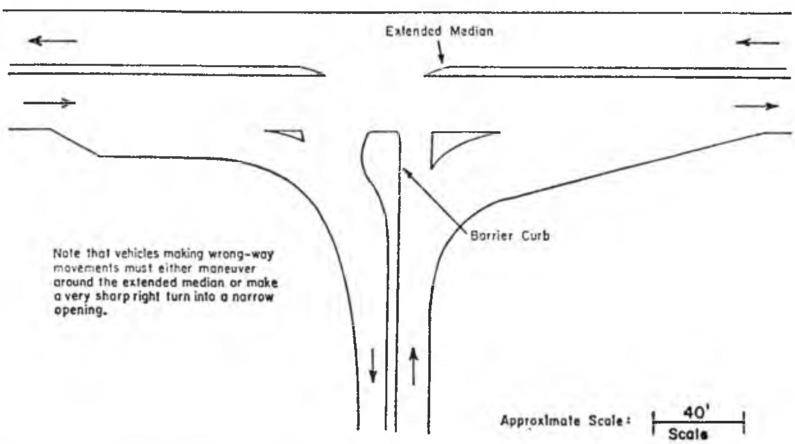

Fig. 14. Wrong-Way Movement Prevention Modifications for a Parclo Interchange.

to approximately two feet and narrowing the off-ramp opening to approximately 12 feet as was suggested for diamond interchanges (Figure 14). To prevent left turns into the wrong opening, the median should be extended to a point where it covers one-third to two-thirds of the off-ramp opening. The noted alterations would make wrong-way movements onto off-ramps a procedure that could only be accomplished with difficulty because of constraints imposed by vehicle-turning radii.

In the case of an undivided crossroad, similar techniques could be used (excluding the median alterations), but wrong-way movement prevention capabilities would be reduced by the absence of a median barrier. Any alterations in medians and curbs, of course, must be consistent with good geometric design practice; more specifically, such alterations must not interfere with exiting traffic's safe and easy use of the off-ramp. Utilizing C-50 minimum radius turning templates, it was determined that medians and curbs can be located in a way that effectively blocks wrong-way movements but leaves exiting vehicles space to make left turns without obstruction. Right turns are not affected by the proposed alterations.

The possibility exists that the proposed wrong-way movement prevention alterations could cause some new operational problems. Such problems, when determined, would need to be evaluated and weighed against the advantages of reduced wrong-way accidents.

Intersections

Because movements in all directions must be provided at intersections of divided highways without fully controlled access, channelization is not a good means of blocking wrong-way movements. However, several elements can be incorporated into intersection design that would tend to make the overall intersection configuration more understandable to drivers. This would probably reduce the frequency of wrong-way movements and certainly improve the overall operation of the intersection. Three principles that would improve intersection visualization are as follows:

1. In a situation where an undivided highway intersects a divided highway, the elevation of the undivided highway should be equal to or greater than that of the divided highway. This would give the approaching motorist (on the undivided highway) a clearer view of both lanes of traffic and make their directions of movement more apparent. Although the undivided road probably carries a smaller volume of traffic, the visualization problem is more critical.

2. Wherever possible, angles of intersection of other than 90 degrees, as well as other unusual layouts, should be avoided. Such layouts are confusing and some of the data gathered for this project indicated that they encourage wrong-way movements.
3. At intersections where cross-median storage space is not required, medians should be narrow but distinct. Narrowing the median will make the far lanes of travel more visible, improving the driver's understanding of the overall intersection. A narrow median would also reduce the amount of unchannelized space that the motorist must negotiate. The median must be distinct to aid the driver in understanding the intersection layout and function. Distinctness can be achieved by both raising and coloring the median.

Driveways

Wrong-way movements from driveway-type access points can be reduced through geometric design modifications. Generally speaking, on all divided highways, driveways not provided with a median opening should be directional. With the use of curbs, exiting vehicles can be channelized so that wrong-way movements are very difficult and the right direction of travel is very obvious (see Figure 15). Such channelization improvements would be relatively inexpensive, easy to install, and would improve overall facility operation.

Transitions

Transitions from an undivided to a divided highway are a relatively frequent source of wrong-way movements, as well as other operational

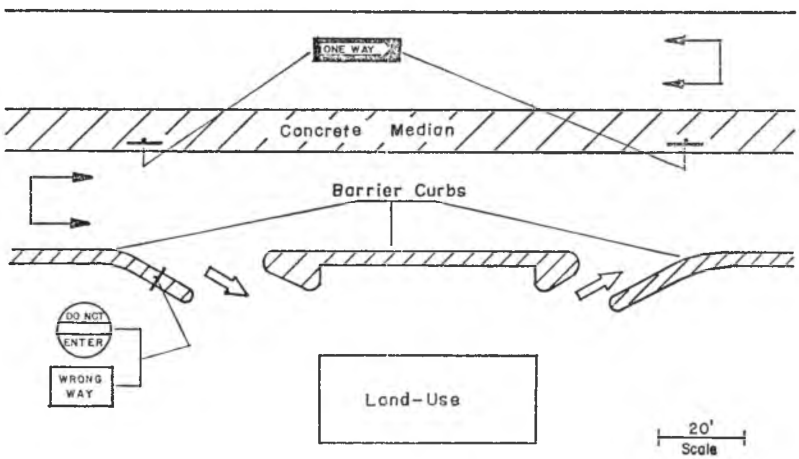

Fig. 15. Possible Directional Driveway Design.

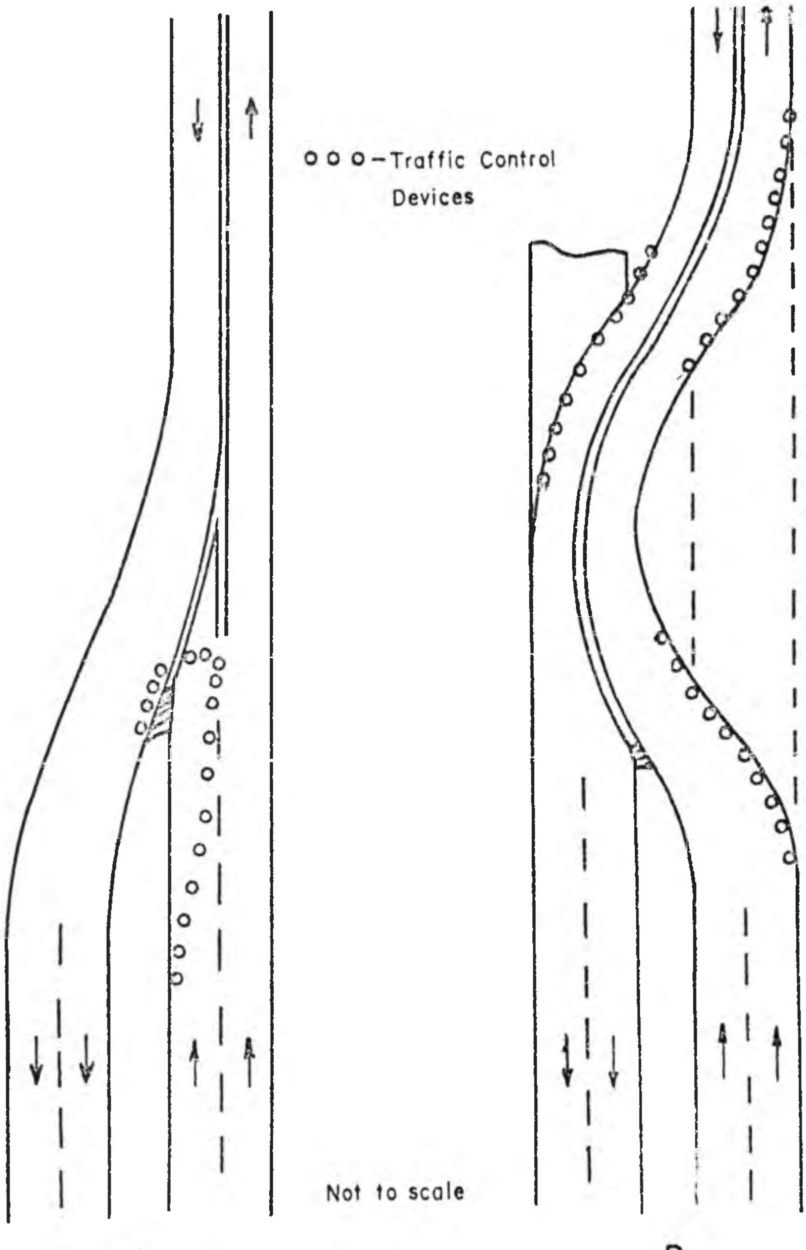

Fig. 16. Two Basic Transition Configurations.

problems. Figure 16 illustrates the two basic transition configurations. Configuration A is very poor design and should never be used as it requires drivers to read and understand signing instructing them to bear right to enter the transition in the right direction. This is not in accordance with the principles developed earlier, namely, that wrong-way movement prevention systems should not depend on signing. Configuration B is much better practice and should always be used.

MAJOR FINDINGS OF THE STUDY

The major findings of this study are summarized below:

1. Of the 96 accidents that occurred during the three-year period, 27 had one or more fatalities, 29 had one or more injuries, and 40 resulted in property damage. Only 37 accidents occurred on fully controlled access highways, but these accounted for 17 of the fatal accidents.
2. Wrong-way accidents are more severe but occur less frequently on highways with fully controlled access than on those without.
3. Wrong-way accidents occur most frequently on Fridays, Saturdays, and Sundays and also between 6 p.m. and 4 a.m. Only 26 percent of the 96 wrong-way accidents occurred during daylight.
4. Wrong-way drivers tend to be drunk (42 of 77 observations), tend to be older, or tend to be driving late at night when they are likely to be fatigued.
5. Only 31 percent of the 96 wrong-way drivers were not adversely influenced by advanced age, fatigue, and/or alcohol consumption.
6. Wrong-way movements tended to originate from areas with low land-use density.
7. Wrong-way movements tended to take place where and when traffic volumes were low. This is probably because when volumes are low, traffic is not present to indicate the correct direction of travel for each roadway.
8. Wrong-way movements tended to take place at times of low visibility.
9. Signing at most wrong-way movement sites was good. Driveway access points were the exception, where little or no signing was the rule.
10. Two types of design elements that had potential to reduce the frequency of wrong-way movements were isolated. Any design

that increases the driver's ability to see and understand the overall intersection configuration would likely reduce wrong-way movements. Also, the use of channelizing islands and curbs to impede potential wrong-way movements appeared to be useful.

11. The ability, motivation, and/or performance of most wrong-way drivers was reduced by adverse influencing factors. Therefore, the most effective wrong-way movement prevention systems will be those which function even if adverse influencing factors are present.
12. Geometric design modifications to reduce wrong-way movements at certain locations were developed. Modifications included channelization at diamond and parclo interchanges and raising the crossroad elevation at divided highway intersections and directional driveways.

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